

CHARACTER EXAMINATION OF THE BASIBRANCHIAL TEETH OF THE FORMOSAN SALMON¹

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(Accepted January 22, 1992)

Kazumi Hosoya, Kun-Hsiung Chang and Ken-Ichi Numachi (1992) Character examination of the basibranchial teeth of the Formosan salmon. *Bull. Inst. Zool., Academia Sinica* 31(3): 213-220. The basibranchial teeth of Formosan salmon, including a syntype of *Salmo saramao*, were reexamined to test the possibility of plural occurrences of salmonids in Taiwan. Branchial osteology and SEM-observation revealed that the teeth are present on the basihyal and absent on the following four posterior basibranchial elements. The basic number of teeth on each side of the basihyal lingual plate is supposed to be six to seven. Our findings support the notion that the Formosan salmon is monospecific and regarded as a subspecies of *Oncorhynchus masou*, i.e., *O.m. formosanus*. This nomenclature is also discussed.

Key words: Basibranchial teeth, Formosan salmon, Lingual plate, Nomenclature, *Oncorhynchus masou* complex, *Salmo saramao*.

The existence of a salmonid in subtropical Taiwan has been cited as a typical example of a glacial relic since its first discovery in the Taiko River (now called the Tachia River) (Aoki, 1917). The Formosan salmon's taxonomic position has been erratically assigned. Oshima (1919) originally described *Salmo saramao* in Japanese, but curiously gave a different name—*Salmo formosanus*—to the salmon's Taiwan population (Jordan and Oshima, 1919). Oshima (1934a, b) revised the *Salmo* taxonomy, regarding Formosan salmon as local population of *Oncorhynchus rhodurus*, Amago. However, Formosan salmon lack the red spots on both body sides which are a diagnostic character of *O. rhodurus*. Referring to

the presence or absence of basibranchial teeth, Behnke *et al.* (1962) suggested that one, two, or three endemic salmonid species persisted in Formosa, while most Japanese and Chinese investigators proposed the existence of a single species (*O. masou*) in Taiwan (Watanabe, 1966; Miyadi *et al.*, 1976; Watanabe and Lin, 1985; Tzeng, 1986).

During our field survey at Wu-Ling Farm in November, 1989 several salmonid specimens were obtained for taxonomic inspection of ad hoc characters. We also reexamined one syntype of *Salmo saramao* which is identical to Formosan salmon. What follows is a preliminary report on our taxonomic review of Formosan salmon which focuses on the basibranchial teeth as a taxonomic character.

1. Paper No. 363 of the Journal Series of the Institute of Zoology, Academia Sinica.

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MATERIALS AND METHODS

The classification of the genus *Oncorhynchus* was newly revised by Smith and Stearly (1989; also see Sanford, 1990); Rainbow and Cutthroat trout were transferred from the genus *Salmo*. The goal of this report is to reexamine the conclusions of Behnke *et al.* (1962), who treated both Rainbow and Cutthroat trout as *Salmo*; in order to avoid taxonomic confusion, the present paper mainly follows Tchernavin (1939) in harmony with the system used by Behnke *et al.* (1962). Our detailed nomenclature for *O. masou* followed that used by Kimura (1990). Abbreviations prefixed to catalogue numbers represent the following Institutions: CAS, California Academy of Sciences; FAKU, Department of Fisheries, Faculty of Agriculture, Kyoto University; FRLM, Fisheries Research Laboratory, Mie University; SU, Stanford University.

Oncorhynchus masou formosanus

Formosan salmon SU 23054 (now preserved at CAS), a syntype of *Salmo saramao*, 120.0 mm SL, collected in a pond at Saramao Police Station, Taiwan. This is the only extant type, mislabelled/misprinted as SU 23059 in the report of Behnke *et al.* (1962) which was also adopted by Watanabe and Lin (1985) without any notice; FAKU 115761-115765, 5 specimens, 159.4-219.0 mm SL, Chichiawan Stream in the Tachia River at Wu-Ling Farm, Taiwan.

Comparative materials

O. masou masou, Sakuramasu-Yamame

FAKU 256654, 1 specimen, 181.7 mm SL, obtained from the fish market in Maizuru, Kyoto Pref., Japan; FAKU-W (Wakasa Bay collection) 328-311, 4 specimens, 146.8-176.1 mm SL, obtained from the fish market in Maizuru, Kyoto Pref., Japan.

O. masou ishikawae, Satsukimasu-Amago

FRLM 11033, 1 specimen, 112.0 mm SL, Kamitsumata Stream on the upper reaches of the Miya River, Mie Pref., Japan; FRLM 11040, 1 specimen, 56.9 mm SL, Hirakura Stream in the Kumozu River, Mie Pref., Japan.

O. masou subsp., Biwamasu

FAKU 115766-115767, 2 specimens, 290.0-355.0 mm SL, Lake Biwa, Imazu-cho, Shiga, Pref. Japan.

Dried skeletal specimens were coated with ionsputter and examined with a JSM-T220A scanning electron microscope.

Terminology for basibranchial

The anteriormost element of the basibranchial series has traditionally been called either the glossohyal (Takagi, 1950; Gosline, 1971) or the basihyal (Goodrich, 1909; Bridge, 1922; Harrington, 1955; McAllister, 1968; Nelson, 1969; Balart, 1985) because of the articulations with a hyoid arch via one pair of the hypohyals. On the other hand, Howes (1978) placed the first basibranchial to the bone in the cephalic osteology of the cyprinid, *Luciobrama macrocephalus*. The histological nature of the anteriormost element is the same as that of the posterior, which is composed of a long bone, the cartilaginous base of the tongue, and dentate membranous coverage. In salmonids, the long bone marking an ossified unit, together with overlying dentate membrane, has been called the lingual plate by Norden (1961), or the supralingual bone by Vladykov (1962). For the present study, the term *basihyal* is used for the anteriormost element, and *lingual plate* for the dentate membrane.

EXAMINATION OF THE BASIBRANCHIAL TEETH

Behnke *et al.* (1962) stressed the peculiarity of the SU syntype (Fig. 1)

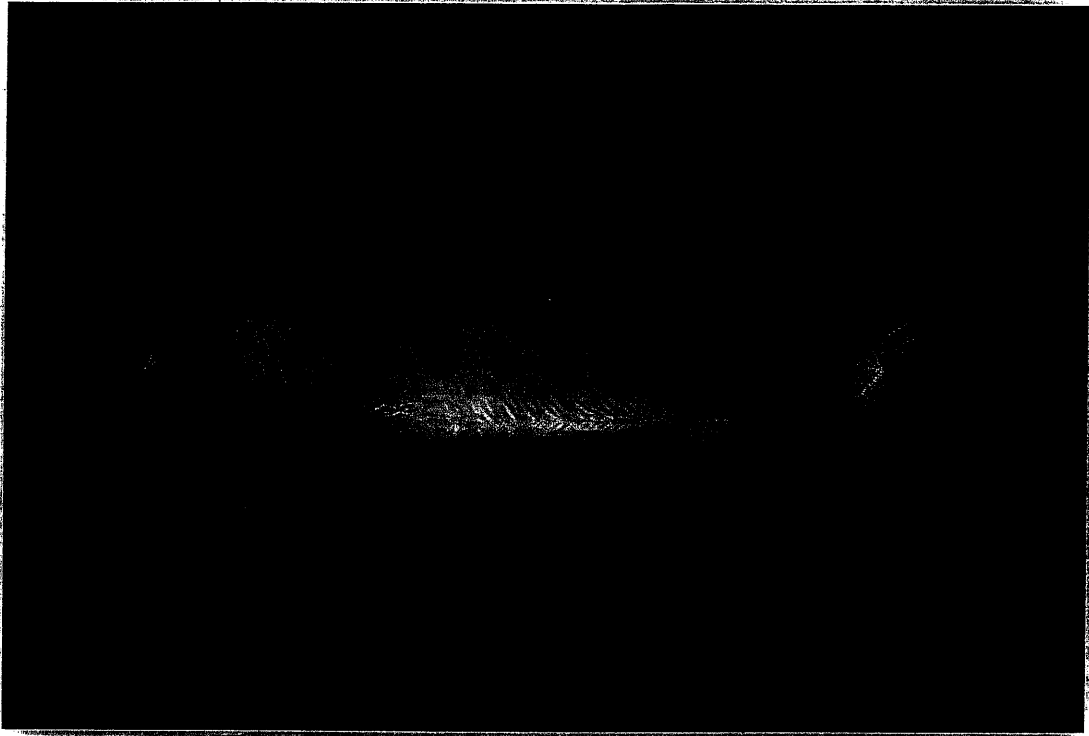


Fig. 1. *Salmo saramao* Oshima (SU23054), a syntype; 120.0 mm SL.

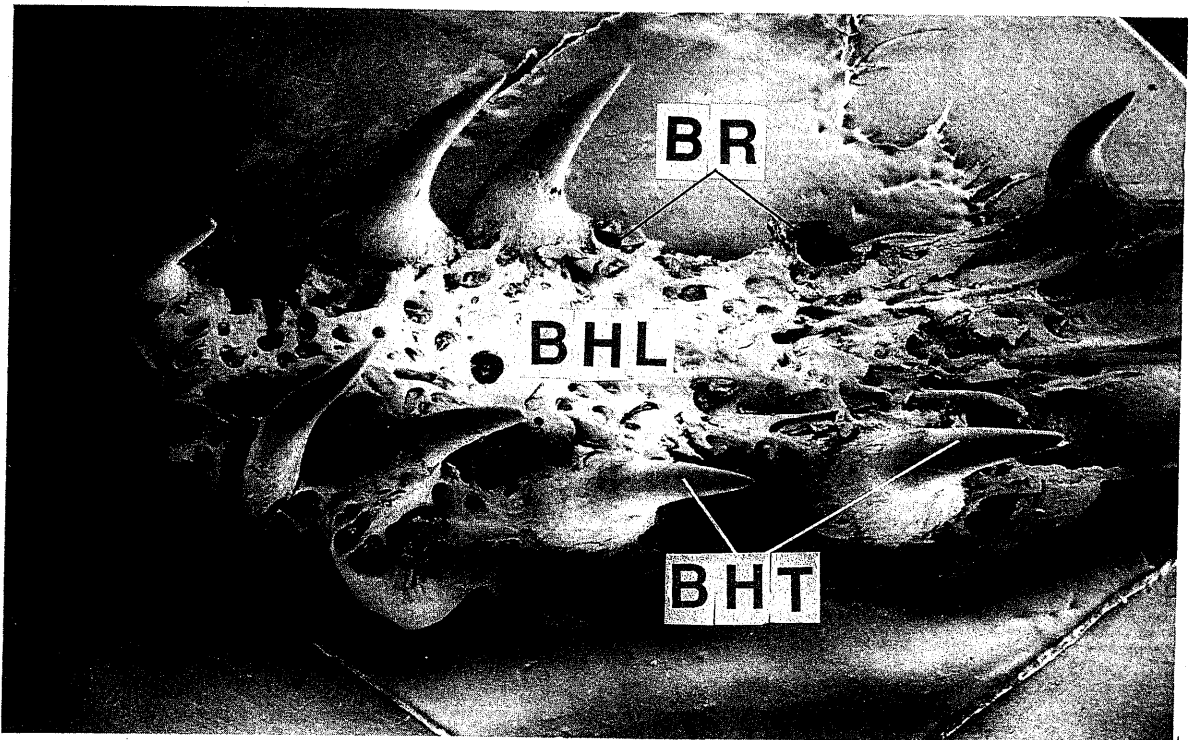


Fig. 2. Dental arrangement on the basihyal lingual plate in *Oncorhynchus masou formosanus*. Dorso-lateral view by SEM ($\times 15$). BHL: basihyal lingual plate; BHT: basihyal teeth; BR: basal recess for the tooth attachment.

having "the basibranchial teeth," which seemed to be a primitive salmonid character, *i.e.*, an attribute of the genus *Salmo* (*sensu* Tchernavin, 1939). However, they remarked that the basibranchials of all the remaining specimens they examined were completely smooth.

The anatomical observations made for the present study, however, differ greatly from those of Behnke *et al.* (1962). The SU syntype surely has teeth on the lingual plate, with an arrangement of six teeth on the left margin and four on the right margin. This dental count does not accord with that of Behnke *et al.* (1962), who concluded (with some uncertainty) that the number of teeth was four. What makes the teeth hard to observe from the outside is that they are usually implanted in the mucous epithelial tissue. Each tooth is ankylosed at the base to the attached lingual plate without mobility (Fig. 2); this designates the so-called "stephanodont"—primitive actinopterygian feature (Fink, 1981). The Formosan salmon is rather specialized in having an unossified portion at the posterior base of the tooth (Fig. 3). A double-stained skeletal specimen of Formosan salmon (FAKU 115761) revealed an arrangement of six teeth on the left margin and five teeth on the right margin of the lingual plate (Fig. 4). The posterior margin of the plate is smooth. When taking into consideration the basal recess for the tooth attachment (Fig. 2, BR), the basic number of teeth on each side is supposed to be six to seven in Formosan salmon. The confirmed teeth in the SU syntype are present only on the basihyal, and absent from the four elements of the basibranchial series. Accordingly, the Formosan salmon—including the SU syntype—turns out to be completely edentate as far as the basibranchial bones are concerned.

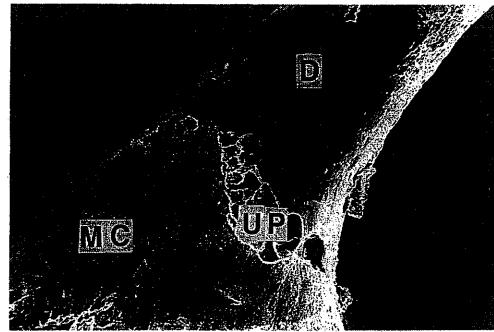


Fig. 3. Tooth attachment on the basihyal lingual plate in *Oncorhynchus masou formosanus*. Posteriolateral view by SEM ($\times 50$). D: dentine; MC: mineralized collagen; UP: unossified portion.

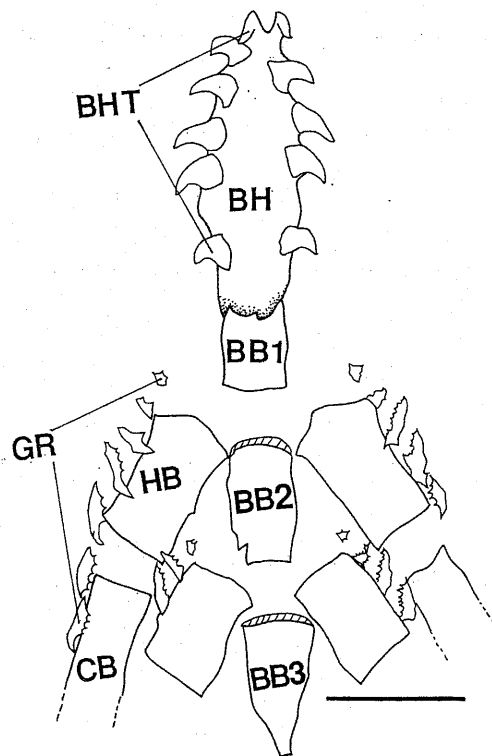


Fig. 4. Basibranchial series and the associated bones of *Oncorhynchus masou formosanus*, dorsal view. Cartilage is cross-hatched. Scale indicates 5 mm. BB: basibranchial; BH: basihyal; BHT: teeth on the basihyal lingual plate; CB: ceratobranchial; GR: gillrakers; HB: hypobranchial.

DISCUSSION

Character validity of the basibranchial teeth

In the basibranchial series of Formosan salmon, the teeth are present on the basihyal and completely absent from the basibranchial elements. Each tooth on the basihyal lingual plate is well developed. This condition is regarded as a strong synapomorphy linking Salmonoidei with Osmeroidei and Argentinoidei (Sanford, 1990). On the contrary, Nelson (1969) designated a primitive feature in the lower teleosts—a small tooth plate occurring over the basihyal and behind an elongated tooth plate over the basibranchial elements; he gave as examples Salmoniformes such as *Retropinna* and *Osmerus*. This primitive condition extends through *Salmo clarki*, *Salvelinus namaycush*, and *Hucho perryi* (Norden, 1961). Judging from character distribution in those salmonid outgroups, the edentate basibranchials may also be regarded as a derived feature. However, it is difficult to say whether a synapomorphy linking *Oncorhynchus* and a few of the *Salmo* species (*i.e.*, Rainbow trout) exists or not, due to its parallel appearance in *Hucho hucho* and *Brachymystax lenok* (Norden, 1961).

Classification of Formosan salmon

Behnke *et al.* (1962) speculated on the the plural occurrence of salmonids in Taiwan, assigning a SU syntype to the genus *Salmo*. The lack of any evolutionary trend toward *Salmo* found in the SU syntype does not support Behnke's assumption. Actually, the SU syntype has the same proportional measurements and meristic counts as *O. masou* (Jan *et al.*, 1990). Watanabe and Lin (1985) concluded that only a single salmonid, *O. masou formosanus*, exists in Taiwan. From the genetic point of view, this conclusion was backed by Numachi *et al.*

(1990).

According to the original description of *Salmo formosanus* (Jordan and Oshima, 1919), this type was reported to have red spots which led to the succeeding synonymization of *Oncorhynchus rhodurus* = *O. masou ishikawae*, Amago by Oshima (1934 a, b). Red spots on both sides of *Salmo formosanus* seemed to be superficial in appearance, as they are composed of canthaxanthin by themselves (Tachikawa *et al.*, 1974; Harada *et al.*, 1974). The presence or absence of red spots is the best and only character which differentiates the Japanese *O. masou* complex. Red spots are apomorphically unique to the fluvial subspecies *O. masou ishikawae*, and the lacustrine form *O. masou* subspecies. On the other hand, *O. masou masou* completely lacks red spots; there was no indication of red spots not only on our specimens, but also on any others described in past papers or photographs made after the original description. Thus, the Formosan salmon is quite identical to *O. masou masou* in color pattern.

Biogeographically speaking, it is more reasonable to classify Formosan salmon as a local population of *O. masou masou* than of *O. masou ishikawae*. The existence of Formosan salmon in Taiwan can be explained by describing it as a southern extension of the *O. masou masou* population from the Sea of Japan via the Tsushima Channel. This migration is supposed to have occurred 100,000–800,000 to no more than one million years ago, when a cold current prevailed in the Sea of Japan (Numachi *et al.*, 1990). On the other hand, forms with red spots, such as *O. masou ishikawae* and the *O. masou* subsp., are confined to those regions surrounding the Seto Inland Sea and the Tokai District of Japan. The distribution of Formosan salmon in Taiwan is out of the normal range of those forms with red spots.

On the basis of our observations, Formosan salmon should be regarded as a local population of *O. masou masou*.

Nomenclature for the Formosan salmon

In giving a subspecific name to Formosan salmon, there is some nominal confusion, *i.e.*, *saramao* vs. *formosanus*. When Oshima (1919) originally described *Salmo saramao*, —with co-author D. S. Jordan—curiously gave it a different name, *Salmo formosanus*, in a separate publication (the Proceedings of the Academy of Natural Sciences, Philadelphia, 71, which was published three months after his original article appeared). Consequently, the earliest name for Formosan salmon is considered to be *Salmo saramao*. Miyad *et al.* (1976) and Yasue (1981) also suggested *Salmo saramao* as a *nomen oblitum* due to its lack of usage for more than fifty years following the original description. Watanabe and Lin (1985) treated it as *nomen oblitum* in their synonymy list of *Oncorhynchus masou formosanus*. However, *Salmo saramao* is still alive at present, since *nomen oblitum*—as a limitation of the law of priority in article 23, 2nd edition of the International Code of Zoological Nomenclature (1964)—was omitted in the 3rd edition (1985). In the interest of nominal stability, the application of *formosanus* to the subspecific name of Formosan salmon is preferable in serving the purpose of article 23 in the 3rd edition, which does not permit the upsetting of a long-accepted name in its accustomed meaning through the introduction of an unused name which was its senior synonym (see art. 79c).

Acknowledgments: Dr. I. Nakamura (FAKU) reviewed an early draft of this paper. Dr. P. K. Tubbs, an executive secretary of the International Commission on Zoological Nomenclature, designated the proper interpretation for the publica-

tion date. Dr. C. S. Tzeng gave the first author (K. H.) every possible facility during his stay in Taiwan. Dr. S. S. Kimura (FRLM) and Mr. David Catania (CAS) kindly loaned valuable registered specimens, including a syntype of *Salmo saramao*. Mr. E. Komiyama offered us some comparative salmonid materials. Dr. T. Okazaki gave us some important suggestions on salmonid evolution. Dr. K. Konishi and Mr. K. Kawamura offered us technical advice. To all the above mentioned investigators, we wish to express our gratitude.

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臺灣產鮭魚基鰓骨齒形質檢定

細谷和海 張 崑 雄 沼知健一

本研究重新檢定臺灣產鮭魚（包括共模標本 *Salmo saramao*）基鰓骨齒的出現情形，以探討臺灣是否可能存在著兩種以上的鮭魚。就鰓部骨骼學上的分析以及以 SEM 觀察，其結果顯示牙齒僅出現在這些鮭魚的基舌骨上，每邊基舌骨舌板上的舌齒一般為6到7枚。而在基舌骨之後的四種基鰓骨上則皆未發現到有牙齒的存在。此項結果可以肯定臺灣產的鮭魚為單一種的說法，並且可以將它認為是 *Oncorhynchus masou* 的一個亞種，學名應為 *O. m. formosanus*。本文並就此命名加以討論。